

The Nearby Early-type Galaxies Survey (ENEAR): Project Description and Some Preliminary Results

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Abstract.

The ENEAR project is an all-sky survey of nearby early-type galaxies. About 2200 new spectra and R -band images of over 1500 galaxies together with published data were assembled into a large catalog containing over 2000 objects with cz , σ , photometric data, and line strengths on a uniform system. From this extensive database a magnitude-limited sample has been drawn comprising ~ 1400 galaxies brighter than $m_B = 14.5$, $cz < 7000 \text{ km s}^{-1}$, and $T \leq -2$ with measured distances (ENEARf) and about 500 early-type galaxies in 28 clusters/groups (ENEARc) to derive an internally consistent $D_n - \sigma$ relation to estimate galaxy distances.

In this contribution we discuss some general properties of ENEAR and briefly describe some preliminary results.

1. Introduction

The importance of cosmic flows to cosmology and to our understanding of the origin and evolution of large-scale structures as well as earlier observational and theoretical work on the subject have been reviewed by Strauss (1999) and Frenk (1999) in this workshop. On the observational side attention has focused on using promising new accurate distance indicators, such as the SBF method (Tonry *et al.* 1999) and SNeIa (Schmidt 1999, Riess 1999). Nevertheless, the FP and TF methods have remained the dominant distance indicators in this field because so far the new methods either do not reach great enough depths or do not provide enough objects for a detailed mapping of the peculiar velocity field.

Most of the recent work in the field involving all-sky samples such as the SFI/SCI (da Costa *et al.* 1996 and Giovanelli *et al.* 1997), Mark III (Willick *et al.* 1997), and SHELLFLOW (Courteau *et al.* 1999) have relied primarily on TF samples. Other recent investigations, using different distance indicators, have been specialized in one way or another (*e.g.*, EFAR Colless *et al.* 1999, Wegner 1996, SMAC Hudson *et al.* 1999, and LP10K Willick *et al.* 1999) and with few exceptions have concentrated on pre-chosen areas of the sky which do not render them optimal for all types of analyses. However, it is apparent from theoretical studies and discussions in this workshop (*e.g.*, Davis 1999, Burstein 1999, Hudson 1999, Kolatt *et al.* 1999, Zehavi 1999, Hoffman 1999) that there is much information to be gained from large dense surveys of peculiar velocities where selection and errors are well understood.

Developments in instrumentation, particularly CCDs, have greatly aided in obtaining improved spectra and photometry and brought much larger samples of improved data quality within reach. The new redshift-distance survey of a magnitude-limited sample of early-type galaxies reported here, comprising 1400 galaxies in about 900 objects within 7000 km s^{-1} , is a substantial enlargement of the available data. The last all-sky elliptical galaxy survey, containing about 550 galaxies in 226 objects is still the 7S study (Faber *et al.* 1989).

For the past several years, the authors combined their resources to carry out an all-sky survey of nearby early-type field and cluster galaxies (E and S0) in order to utilize the FP relation to measure their V_{pec} for redshifts $cz < 7000 \text{ km s}^{-1}$, hence the name ‘ENEAR.’ The general purpose of ENEAR was to study large-scale motions based on early-type galaxies to a comparable depth to that reached by the SFI TF sample. Such a sample will allow a comparison between the motions of spirals and ellipticals, based on different distance relations, and their combination will provide an even denser set of probes of gravity in the nearby universe. In addition, the new spectroscopy provides the important by-product of linestrengths with which galaxies in different environments can be compared.

2. Definition of the ENEARf Sample

The ENEARf sample provides all-sky coverage, except for the usual lack of data along the galactic equator, and consists of galaxies with m_B brighter than 14.5 mag and $cz < 7000 \text{ km s}^{-1}$. Morphological types are limited to $T \leq -2$. A number of catalogs were used to construct the initial all-sky catalog from which the early-type subsample was drawn. Among them CfA1 (Huchra *et al.* 1983), SSRS (da Costa *et al.* 1991) and the equatorial survey (Huchra *et al.* 1990) at high galactic latitudes (Pellegrini *et al.* 1990), and the ORS sample (Santiago *et al.* 1995) at lower $|b|$. Combined these samples give full sky coverage to the desired depth, but required slight adjustments in magnitude and morphological type scales. A more detailed description of the sample will be presented elsewhere (da Costa *et al.* 2000a).

3. The New Observations

The new observations consist of 2200 spectra of about 1650 galaxies and 2100 R -band CCD images of 1580 galaxies. The bulk of the northern hemisphere observations were made at the MDM Observatory using the 2.4 m Hiltner and 1.3 m McGraw-Hill telescopes. The southern hemisphere imaging observations were made using different telescopes at ESO and the 0.9m at CTIO, while the spectroscopic observations were carried out primarily at the ESO 1.5m telescope. The data from both hemispheres were overlapped in order to get a good handle on possible systematic errors. Northern hemisphere data extended to $\delta = -20^\circ$ and southern hemisphere observations were carried out to $\delta = +20^\circ$.

The observational setups, procedures, and data reductions are similar to those given in Wegner *et al.* (1999) and Saglia *et al.* (1997). They will be described in detail in Wegner *et al.* (2000) and Alonso *et al.* (2000). For spectroscopic data, there are about 500 galaxies with two or more observations and about 200 galaxies with measurements available in the literature. We estimate that our internal errors are typically 8% in velocity dispersion and 0.01 mag in M_{g_2} . For photometric data, there are about 500 galaxies with repeated observations and over 300 with measurements publicly available. Errors in the global parameters are estimated to be: 0.017 dex in $\log D_n$, 0.08 dex in $\log r_e$, 0.3 mag/arcsec² in $\bar{\mu}_e$, 0.019 in $FP = \log r_e - 0.30 \bar{\mu}_e$, and 0.09 mag in the total magnitude. The large number of repeated observations and the overlap with published data sets is key to bring all measurements into a common a system and to produce a homogeneous sample.

4. Sky Coverage and Completeness

The projected positions of the observed ENEARf galaxies on the sky in galactic coordinates is shown in Figure 1 where they are compared with the distribution of the spiral galaxies from the SFI sample. As can be seen while the total number of galaxies with measured distances is comparable to that of SFI, the distribution of ENEARf galaxies is visibly more clumpy, better delineating the high-density regions of the nearby universe. After assigning galaxies to groups the total number of independent objects is ~ 850 . Figure 2 compares the ENEARf sample

with that of the 7S (E's) in three redshift shells, after grouping. This figure illustrates the relatively dense sampling accomplished by the ENEAR project compared to the older data. It is important to note the differences between the two samples in the Perseus-Pisces region, a source of great debate in the past.

The completeness of the sample, as judged by a comparison with the total number of objects that could have been observed, is about 70% complete within the chosen redshift and magnitude cutoff. The remaining galaxies are predominantly lenticular galaxies. However, it is important to emphasize that the level of completeness of the sample is uniform across the sky.

5. Groups and Clusters

The ENEAR sample also complements recent work on early-type galaxies in clusters; at the moment 446 elliptical and S0 galaxies have been assigned to 28 clusters (ENEARc) and used to derive the $D_n - \sigma$ relation. Some of the clusters in the ENEARc sample include ENEARf galaxies while others lie beyond 7000 km s^{-1} to include previously well-studied clusters. Information on the cluster sample and the distances and motions of the clusters will be reported in Bernardi *et al.* (2000a, b).

In contrast to earlier work, groups and clusters with $cz \lesssim 7000 \text{ km s}^{-1}$ were identified by an objective algorithm applied to the original all-sky sample with complete redshift information. Fainter galaxies were assigned to the identified groups or clusters using well-defined criteria. Systems with more than five early-type member galaxies were used in the definition of the distance relation. The adopted membership assignment procedure is considerably superior to those utilized in the past when only incomplete redshift information was available. The identification of groups also permits a much improved grouping of galaxies, which is critical for studies of the peculiar velocity field using early-type galaxies.

In Bernardi *et al.* (1998) we have used this objective membership assignment to compare the properties of early-type galaxies in different environments using the Mg_2 line index and the central velocity dispersion σ . We have found that the $\text{Mg}_2 - \sigma$ relation does not show any dependence on environment. This result favors a scenario of formation and evolution of early-type galaxies in which the bulk of stellar populations in galactic spheroids formed at high redshift ($z \gtrsim 3$), no matter whether such spheroids now reside in high or low density regions. Furthermore, the lack of environmental effects also supports the assumption that the empirical distance indicators such as the $D_n - \sigma$ relation determined using cluster galaxies, are universal; this is a crucial assumption for peculiar velocity field analyses.

6. Distances and Motions

We use our homogeneous data for 28 clusters/groups to determine an internally consistent, bias corrected $D_n - \sigma$ relation (Bernardi *et al.* 2000b). We have fitted the following regression:

$$\log D_n = 1.180 \log \sigma + 1.391.$$

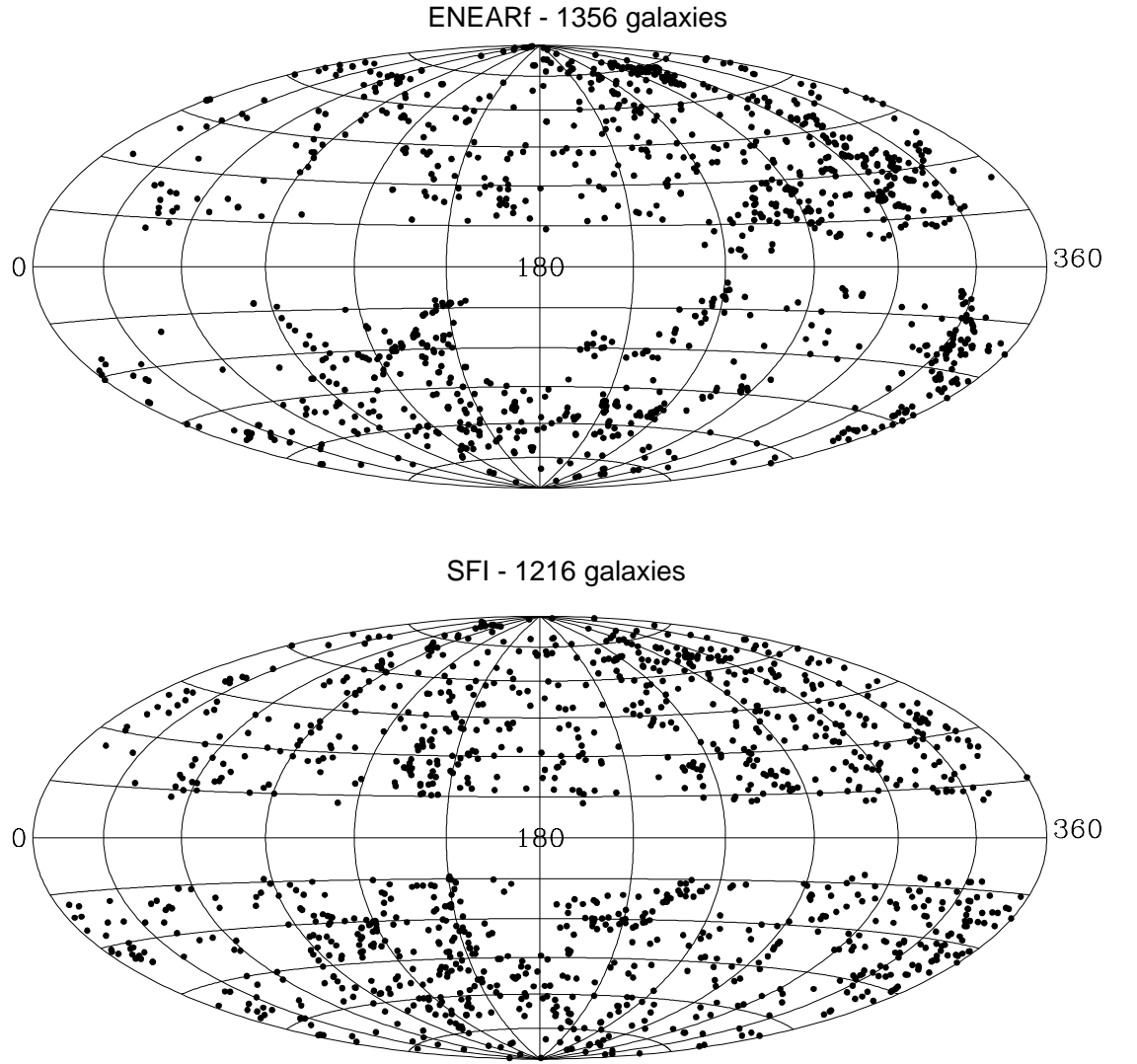


Figure 1. Comparison of the projected distributions of galaxies with available peculiar velocities on the sky in galactic coordinates for the ENEARf and the SFI samples.

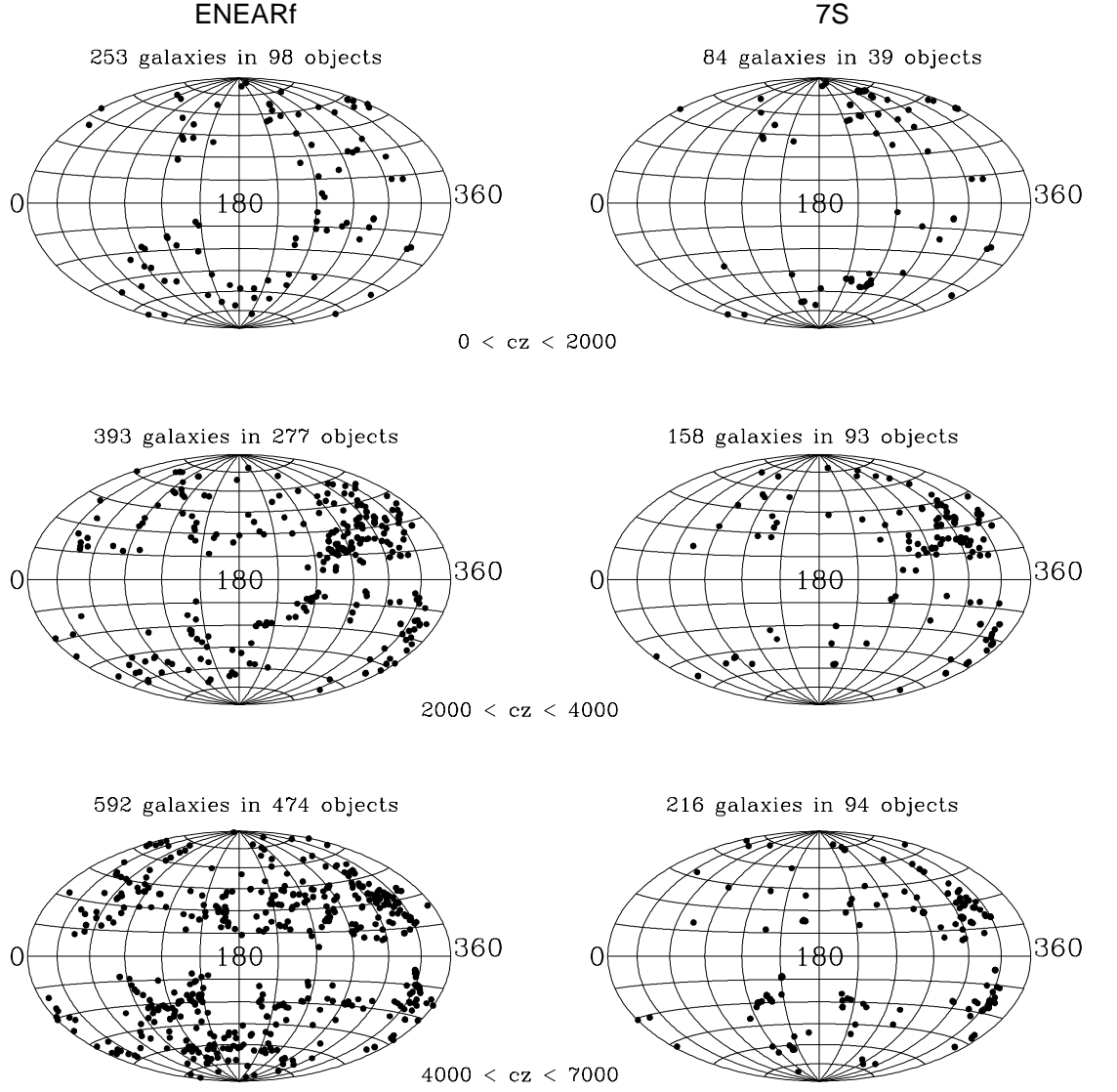


Figure 2. Comparison of the early-type galaxies observed in the EN-EARf sample and the 7S survey projected on the sky in galactic coordinates and in three redshift shells.

These coefficients are quite close to those found by the 7S (Faber *et al.* 1989). The scatter in the derived distance relation corresponds to a distance error of about 19% per galaxy, comparable to what is obtained for the FP relation. The above $D_n - \sigma$ relation is used to find distances and peculiar velocities for all objects (individual galaxies and groups) in the ENEARf sample. Using the radial components of the peculiar velocity we fit a a dipole flow model for which we find (da Costa *et al.* 2000b):

$$V = 343 \pm 53 \text{ km s}^{-1}, \quad l = 264^\circ \pm 8^\circ, \quad \text{and} \quad b = 33^\circ \pm 5^\circ.$$

This direction is close to the direction of the LG motion and consistent to the one found in the recent cluster study of Dale *et al.* (1999).

7. Conclusions

The observational phase of the ENEAR project is approaching completion. More detailed descriptions of all portions of the project and analysis will be given in a forthcoming series of papers. At this time our main goal has been to show the scope and coverage of the database. For peculiar motions, the ENEAR sample complements the SFI study for spirals in depth, number of galaxies, and accuracy of observations. Our preliminary look at the data shows that the observed peculiar motions of the early-type galaxies in ENEAR is similar to that found from the SFI (Zaroubi *et al.* 2000), suggesting that an accurate picture of the velocity field in the local universe is finally emerging.

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